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(71) Applicant(s)

Sharp Kabushiki Kaisha
(Incorporated in Japan)
22-22 Nagaike-cho, Abeno-ku, Osaka 545-8522, Japan

(72) Inventor(s)

Henning Molsen
Martin David Tillin

(74) Agent and/or Address for Service

Marks & Clerk
4220 Nash Court, Oxford Business Park South,
OXFORD, OX4 2RU, United Kingdom

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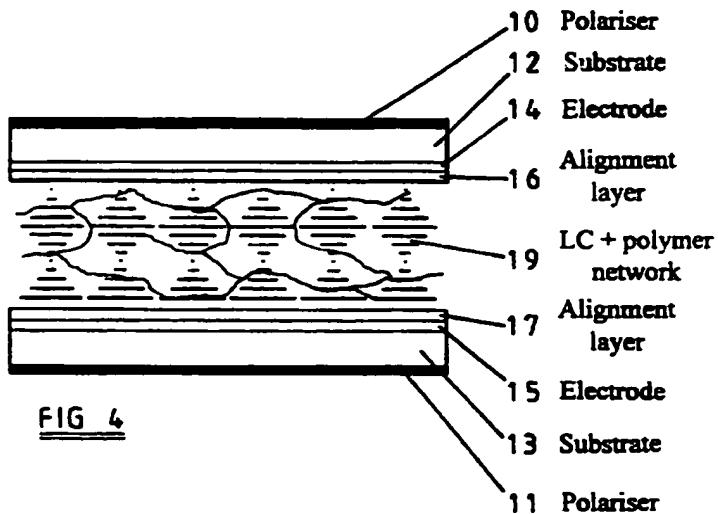
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(54) Abstract Title

Supertwisted nematic liquid crystal

(57) A supertwisted nematic liquid crystal device comprises substrates 12 and 13 carrying external polarisers 10 and 11, electrodes 14 and 15, and alignment layers 16 and 17. The resulting liquid crystal cell is filled by a mixture 18 comprising a nematic liquid crystal and at least one chiral prepolymer having at least two polymerisable groups, such as a diacrylate. The prepolymer is polymerised or crosslinked to form a helical polymer network.



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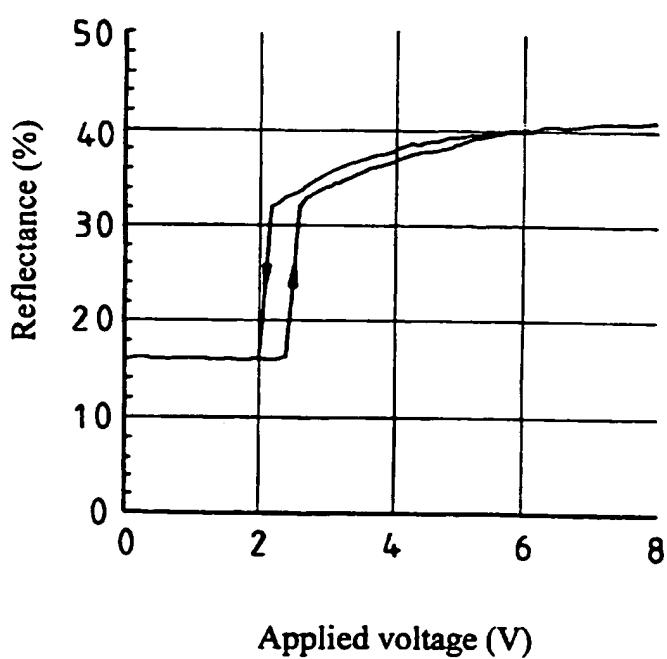
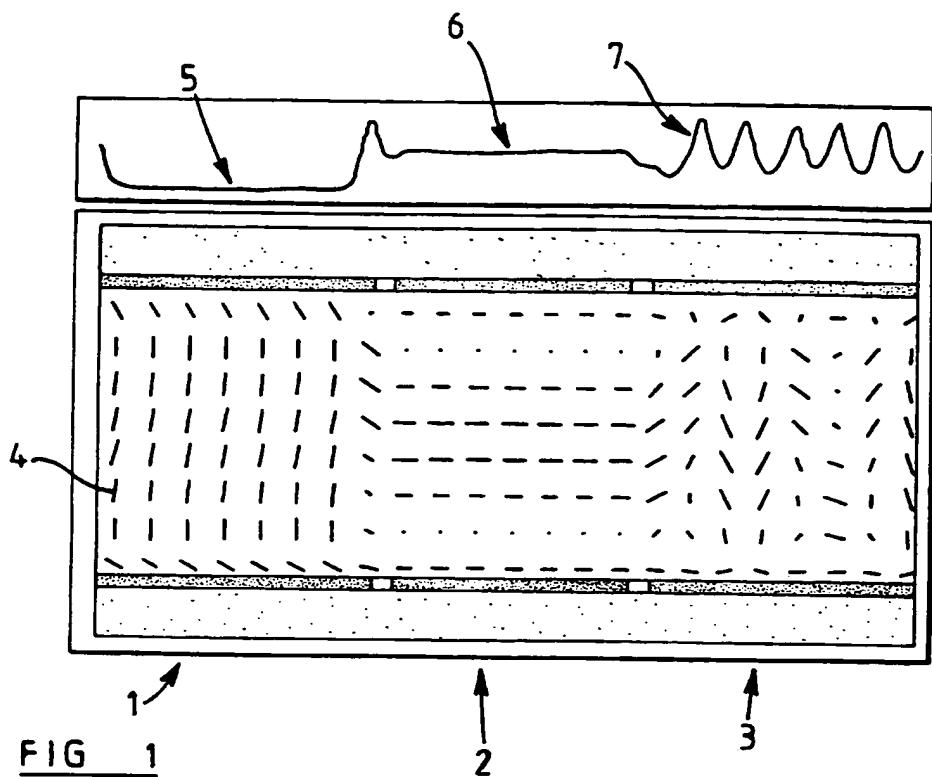
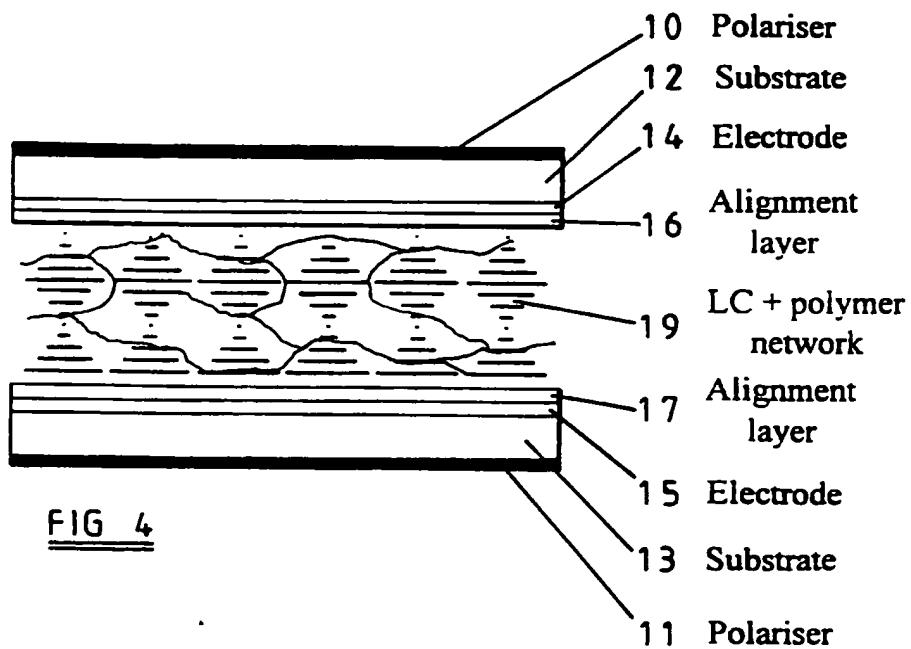
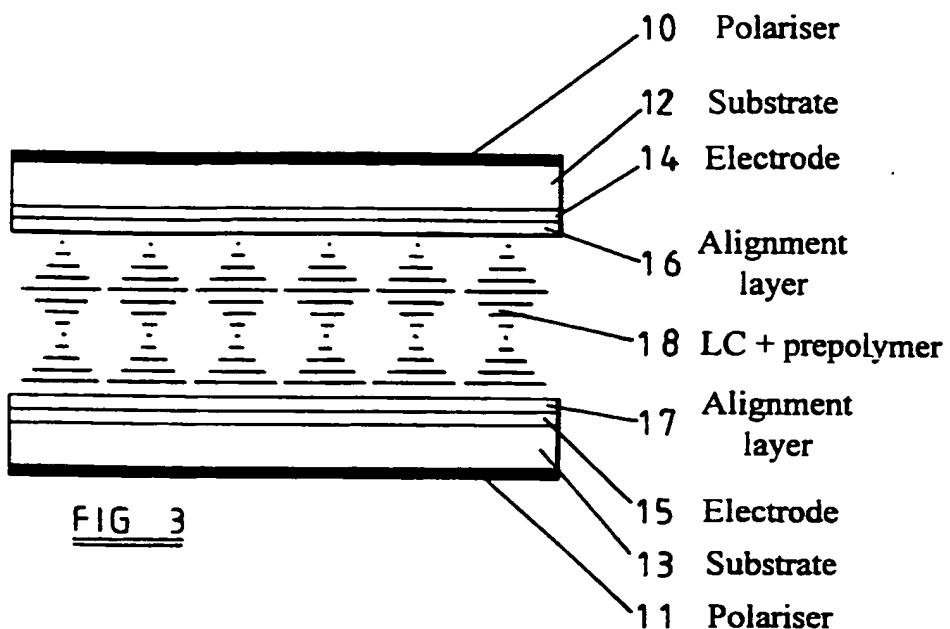
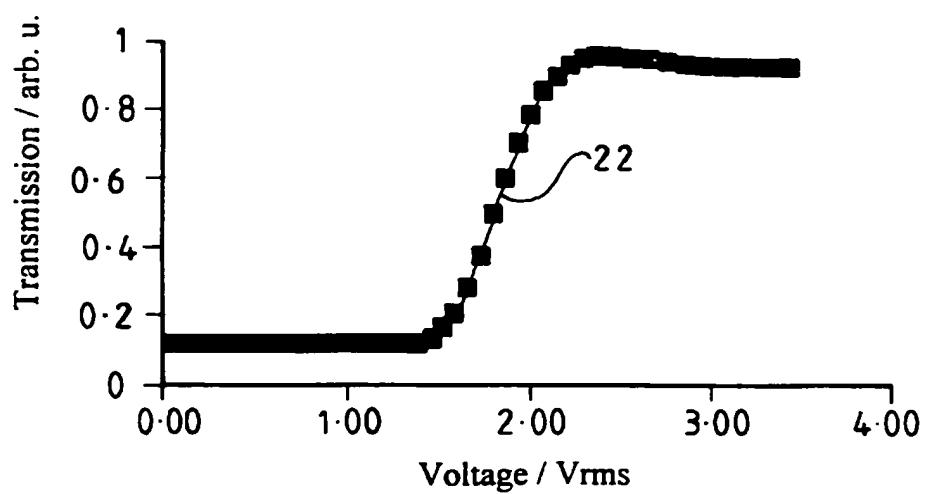
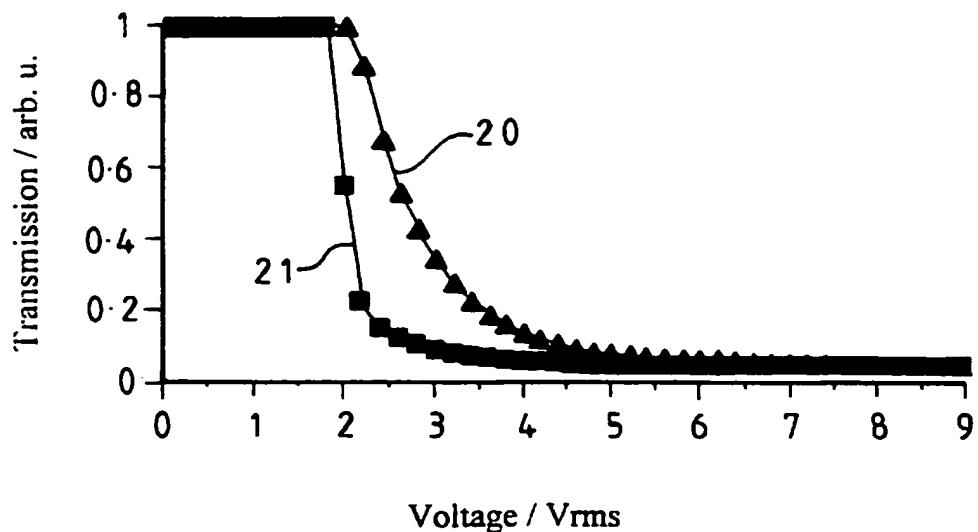
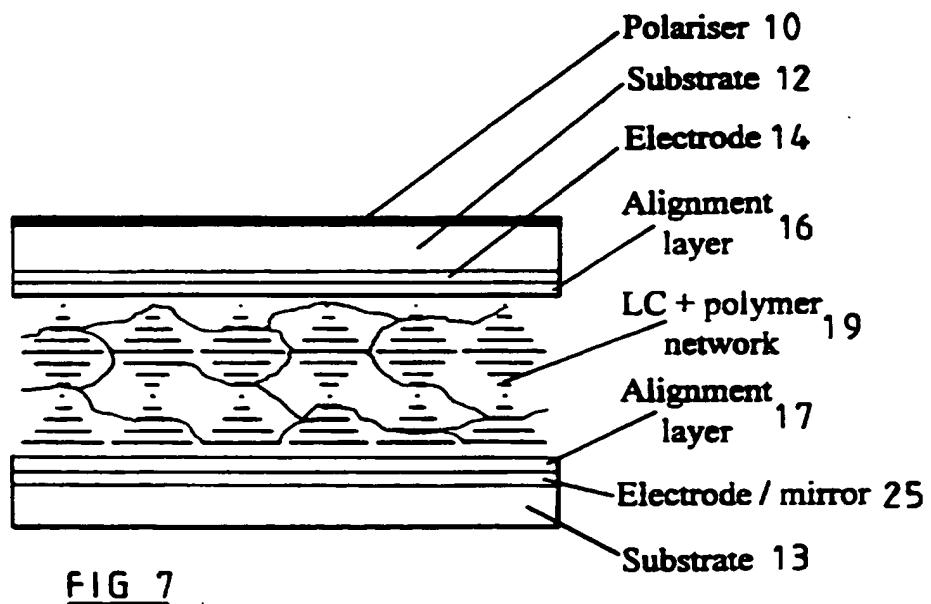
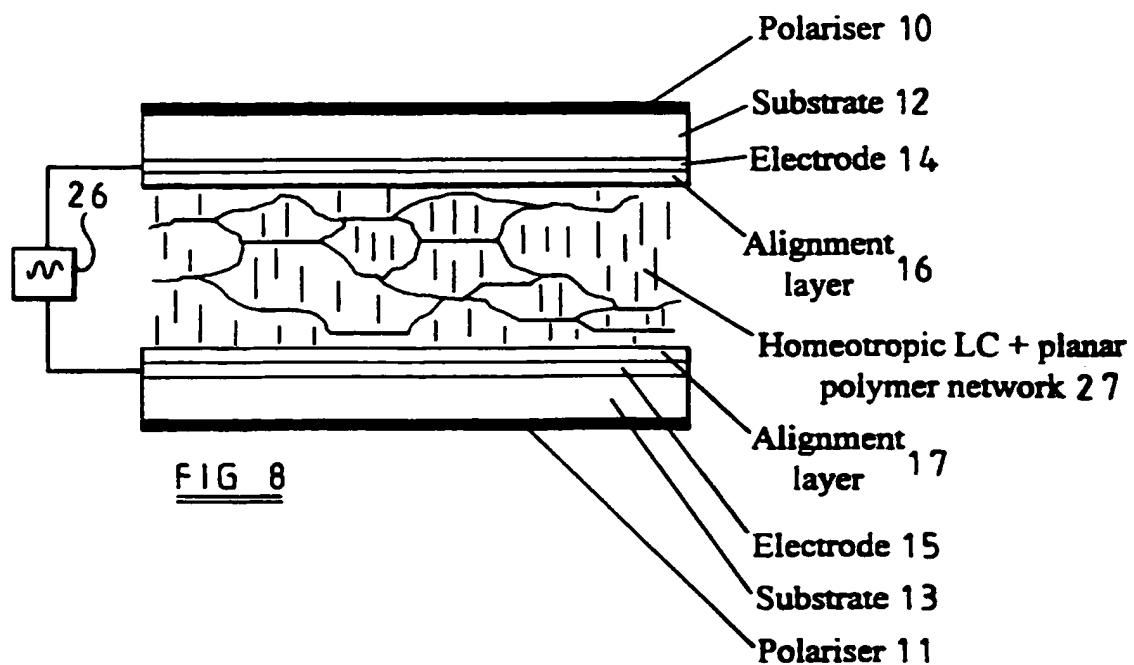


FIG 2







**SUPERTWISTED NEMATIC LIQUID CRYSTAL DEVICE AND METHOD OF
MAKING SUCH A DEVICE**

The present invention relates to a supertwisted nematic liquid crystal device and to a method of making such a device.

Supertwisted nematic (STN) liquid crystal devices (LCDs) are known for use in displays and are disclosed, for instance, in C M Waters et al, "Mol Cryst Liq Cryst" Vol 123 pp 303 (1985). In such devices, a nematic liquid crystal is disposed in a cell and is arranged to have a twist angle typically of the order of 270 degrees. Design rules for STN displays are disclosed by Waters et al and the influence of various parameters, such as surface pre-tilt, twist angle and elastic constants, are explored.

In such STN devices, each picture element (pixel) is individually controllable so as to be switchable between a bright transmissive or reflective state and a dark transmissive or reflective state. Depending on the construction of the device, these two states correspond to the essentially planar orientation and the field-induced homeotropic orientation of the liquid crystal director.

The transition from the planar orientation to the homeotropic orientation is achieved by applying an electric field along the helical axis of the liquid crystal. This can result in either of two competing deformations of the helical pattern of the directors of the liquid crystal molecules. The first is the so-called Freedericksz transition in which the orientation of the local director changes only along a spatial co-ordinate substantially perpendicular to the liquid crystal layer. This is the desired transition. However, the second type of deformation results in a striped texture in which the local optic axis changes its orientation along two spatial co-ordinates, one of which is perpendicular to the liquid crystal layer and the other of which is parallel to the liquid crystal layer. This is disclosed by T Scheffer et al, "Twisted nematic and Supertwisted Nematic Mode LCDs" in "Liquid Crystals - Applications and Uses" Vol 1 pp 232 published by World Scientific Publishing Co Pte Ltd, Singapore 1990. For twist angles of up to about 300

degrees with typical liquid crystals, the stripes are oriented substantially perpendicularly to the local director in the middle of the liquid crystal layer. This transition results in optical hysteresis for relatively low magnitude applied fields, scattering and irreproducible transmission characteristics.

Figure 1 illustrates diagrammatically an STNLCD having three sections or pixels operating in the field-induced homeotropic orientation at 1, in the planar orientation at 2, and with the striped texture at 3. In the field-induced homeotropic orientation, an electric field is applied across the liquid crystal layer of the pixel so that the liquid crystal molecule directors, indicated by short lines such as 4, are oriented throughout the bulk of the liquid crystal layer substantially perpendicularly to the layer. In the planar orientation illustrated at 2, the liquid crystal molecule directors 4 turn through an angle of, for instance, substantially 270 degrees from one surface of the liquid crystal to the other surface thereof. This is the relaxed state of the liquid crystal with no applied electric field across the liquid crystal layer of the pixel.

In the striped texture illustrated at 3, the liquid crystal molecule directors 4 are twisted about an axis perpendicular to the liquid crystal layer, but are also rotated in planes containing that axis.

The graph above the liquid crystal device illustrated in Figure 1 indicates the light transmission for the liquid crystal cell disposed between linear polarisers having orthogonal polarisation directions. In the homeotropic texture illustrated at 1, the birefringence of the liquid crystal layer is such as to have little effect on the polarisation of light passing through the pixel. This is substantially equivalent to the effect of crossed polarisers so that the light transmissivity of the pixel is relatively low, as indicated by the curve at 5.

In the planar texture as illustrated at 2, the liquid crystal layer of the pixel has a birefringence such as to rotate the polarisation of light passing through the layer by 90 degrees. Accordingly, light leaving the pixel has a linear polarisation such that the output polariser provides relatively little attenuation and the pixel appears bright, as indicated by the curve at 6.

The striped texture illustrated at 3 provides a birefringence which varies periodically across the pixel. This leads to light and dark bands as illustrated by the undulating transmissivity curve at 7.

The striped texture is promoted by increasing twist angle and by reducing surface pre-tilt angles in the liquid crystal layer. For instance, Waters et al disclose that increasing the surface pre-tilt lowers the threshold voltage of the Fredericksz transition so as to avoid the formation of the striped texture. However, increasing the surface pre-tilt also increases the relaxation time of the transition from the homeotropic orientation to the planar orientation because the restoring surface forces become smaller as the surface pre-tilt increases. Accordingly, STNLCDs are designed as a compromise between the maximum refresh rate of the display and the likelihood of the occurrence of the striped texture.

D Fredley et al, Journal of the SID Vol 4 pp 89 (1996) discloses a conventional STNLCD in which a non-chiral non-mesogenic acrylate is cured by ultraviolet radiation while applying a high voltage across the liquid crystal cell to create a polymer network which is aligned substantially homeotropically in the cell. This technique is used to increase the tilt angle in the bulk of the liquid crystal layer, even in the "field-off" state. However, the need to apply a high voltage across the cell during manufacture is a considerable disadvantage because of the increased complexity and cost.

H Takatsu et al, SID95 Digest pp 579 (1995) disclose a guest-host liquid crystal device comprising a cell containing a mixture of nematic liquid crystal, a chiral monoacrylate prepolymer and a black dichroic mixture dye aligned on an alignment layer which gives

a low pre-tilt angle of the order of 1 degree. The prepolymer is cured by ultraviolet light which creates a helical side chain polymer. The ratio of the thickness of the liquid crystal cell to the pitch of the helical polymer is made greater than or equal to 1.25. Such a device shows no focal conic texture and this is said to result from the vanishing twisting power of the fixed chiral polymeric dopant.

When a device of this type is used with a reflector on one side of the liquid crystal cell, a performance of the type illustrated in Figure 2 of the accompanying drawings is achieved. The graph of Figure 2 illustrates reflectance as a percentage against applied voltage for a typical cell of this type. As the voltage rises above a threshold of approximately 2.5 volts, the reflectance increases rapidly to a value above 30% and then rises more gently to a maximum reflectance slightly more than 40%. As the voltage is then decreased, the reflectance falls at first relatively slowly and then relatively rapidly to a relatively low or minimum value at 2 volts.

As is clear from Figure 2, the electrooptic performance of devices of this type possesses hysteresis. The presence of hysteresis is a substantial disadvantage because, when addressing a desired transmission state corresponding to a desired grey level, the addressing device is being switched from a brighter or darker state than the desired grey level. Conversely, if the same addressing voltage is used to address an intermediate grey level from brighter and darker states, the actual intermediate level achieved depends on whether the device is switched from a brighter or darker state. In order to avoid these problems with devices exhibiting hysteresis, it is necessary to ensure that, during each refresh cycle, the pixels are first reset to a common, generally dark, state before addressing the next desired state. However, this adds complexity and increases the time required to refresh the device.

According to a first aspect of the invention, there is provided a supertwisted nematic liquid crystal device comprising first and second substrates defining therebetween a cell containing a mixture of a nematic liquid crystal and a helical polymer network.

The nematic liquid crystal in the cell may have a twist angle of between substantially 180° and substantially 360° . The twist angle may be greater than 240° . The twist angle may be substantially equal to 270° .

The nematic liquid crystal in the cell may have a pre-tilt angle less than 4° . The pre-tilt angle may be substantially equal to 2° . The term "pre-tilt angle" is well known in the liquid crystal field and refers to the angle at which the liquid crystal director is tilted out of the substrate plane due to interaction with an alignment layer.

At least one of the first and second substrates may have an alignment layer for inducing planar alignment.

The polymer of the network may be a networked polymer. The term "networked polymer" as used herein refers to a polymer in a liquid crystal environment which is formed in a liquid crystal phase from mesogenic precursors having polymerisable moieties which can link to more than two other mesogenic precursors. The polymer may comprise at least one polymerised chiral prepolymer having at least two polymerisable or crosslinkable groups. The prepolymer may comprise a diacrylate.

The polymer network may comprise at least 1% by weight of the mixture. The polymer network may comprise at least 1.5% by weight of the mixture.

The polymer network may comprise less than 20% by weight of the mixture. The polymer network may comprise less than 10% by weight of the mixture. The polymer network may comprise less than 5% by weight of the mixture.

The cell may be disposed between first and second polarisers. The first and second polarisers may have linear polarising directions oriented at between 0° and 90° with respect to each other.

The cell may be disposed between a polariser and a reflector.

An optical retarder may be disposed between the mixture and the polariser or between the mixture and the reflector.

According to a second aspect of the invention, there is provided a method of making a supertwisted nematic liquid crystal device, comprising juxtaposing first and second substrates to define there between a cell, filling the cell with a mixture comprising a nematic liquid crystal and a chiral prepolymer, and polymerising or crosslinking the prepolymer to form a polymer network.

The mixture may comprise a non-chiral prepolymer in addition to the chiral prepolymer.

The prepolymer may be a networkable prepolymer.

The chiral prepolymer may have at least two polymerisable or crosslinkable groups.

The prepolymer may comprise a diacrylate.

The nematic liquid crystal in the cell may have a twist angle of between substantially 180° and substantially 360°. The twist angle may be greater than 240°. The twist angle may be substantially equal to 270°.

The nematic liquid crystal in the cell may have a pre-tilt angle less than 4°. The pre-tilt angle may be substantially equal to 2°.

The method may comprise forming on at least one of the first and second substrates, prior to the juxtaposition, an alignment layer for inducing planar alignment.

The prepolymer may comprise at least 1% by weight of the mixture. The prepolymer may comprise at least 1.5% by weight of the mixture.

The prepolymer may comprise less than 20% by weight of the mixture. The prepolymer may comprise less than 10% by weight of the mixture. The prepolymer may comprise less than 5% by weight of the mixture.

The liquid crystal may have positive dielectric anisotropy and the polymerising or crosslinking may be performed in the absence of an applied field across the cell.

The liquid crystal may have negative dielectric anisotropy and, during polymerising or crosslinking, a field which provides planar alignment of the liquid crystal may be applied across the cell.

Locking the chirality in a polymer network prevents or substantially reduces the possibility of the formation of the striped texture. It is thus possible to produce a 270° STN device with an alignment layer inducing a pre-tilt of 2° which can be commercially manufactured. Such a device is advantageous compared with known STN devices where the twist is limited to 240° with alignment layers inducing a relatively high pre-tilt, for instance greater than 4°. Further, it is possible to avoid the use of commercially unviable evaporated alignment layers, such as silicon oxide, which would otherwise be required in order to provide high pre-tilt alignment layers permitting a 270° twist.

The use of a networked polymer instead of a side chain polymer provides more stable polymer orientation and avoids hysteresis in the electrooptic curve. The use of low pre-tilt alignment layers reduces device switching times so that the required time to switch between the two states of a typical device may be of the order 40 milliseconds.

The invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic cross sectional view with associated transmissivity curves of a known type of STN device;

Figure 2 is a graph of reflectance in per cent against applied voltage illustrating an electrooptic curve of a known type of twisted nematic liquid crystal device including a black dichroic dye mixture;

Figure 3 is a diagrammatic cross-sectional view of an STN device prior to polymerisation or crosslinking;

Figure 4 is a diagrammatic cross-sectional view of the device of Figure 3 after polymerisation or crosslinking to provide an STNLCD constituting a first embodiment of the invention;

Figure 5 is a graph of transmittance against applied voltage for the devices shown in Figure 3 and 4 with cross polarisers;

Figure 6 is a graph of transmittance in arbitrary units against applied voltage for a device of the type shown in Figure 4 with parallel polarisers;

Figure 7 is a diagrammatic cross-sectional view of an STNLCD of the reflective type constituting a second embodiment of the invention; and

Figure 8 is a diagrammatic cross-sectional view of an STNLCD constituting a third embodiment of the invention.

Like reference numerals refer to like parts throughout the drawings.

The device shown in Figure 3 comprises a liquid crystal cell disposed between external polarisers 10 and 11. The polarisers 10 and 11 are linear polarisers and their polarisation directions may be between 0^0 and 90^0 with respect to each other.

The liquid crystal cell comprises an upper substrate 12 and a lower substrate 13. The substrates 12 and 13 carry addressing arrangements shown as electrodes 14 and 15. For

instance, in the case of passive matrix addressing, the electrodes 14 and 15, which are transparent and may be made of indium tin oxide (ITO), comprise parallel strips oriented such that the longitudinal direction of the electrodes 14 is orthogonal to the longitudinal direction of the electrodes 15. The intersections or overlaps of the electrodes 14 and 15 define picture elements (pixels) which are independently addressable.

Alternatively, an active matrix addressing arrangement may be provided. In such an arrangement, one of the electrodes such as 15 is a plan electrode, ie: extends substantially continuously throughout the device. The other electrode, such as 14, is divided into individual pixel electrodes, each of which is controlled by one or more active devices provided on the substrate 12, for instance, in the form of thin film transistors made by silicon-on-glass- techniques.

The electrodes 14 and 15 are covered by alignment layers 16 and 17, respectively. Two alignment layers are shown in the embodiment illustrated in Figure 3 but, in alternative arrangements, it is possible to omit one of the alignment layers. The alignment layers 16 and 17 are, for instance, made of rubbed polyimide, such as P12555 available from Dupont, with the rubbing directions being orthogonal and such as to provide a left-handed liquid crystal twist. The alignment layers provide a relatively low pre-tilt angle, for instance of 2 degrees.

During manufacture, the liquid crystal cell is filled with a mixture 18 comprising a liquid crystal and a prepolymer. For example, the liquid crystal may be of a nematic type and may comprise ZLI2293 available from Merck in Germany. The prepolymer may comprise a chiral diacrylate and a non-chiral diacrylate. The chiral diacrylate comprises 0.42% by weight of the mixture and may be LC481 which is available from BASF in Germany and which has a helical twisting power substantially equal to 34.5 per micrometre. The non-chiral diacrylate may comprise 1.5% by weight of the mixture and may be RM258 available from Merck in the UK.

The device comprises a supertwisted nematic device with the liquid crystal in the mixture 18 exhibiting a twist substantially equal to 270°, the helical pitch being substantially equal to 6.7 micrometres.

The diacrylates in the mixture 18 are photopolymerisable and, after filling of the cell, are exposed to Type A ultraviolet radiation with an intensity of 14 milliwatts per square centimetre applied for 30 seconds. As a result, the diacrylates are crosslinked to form a polymer network so that the cell contains a mixture of the liquid crystal and the polymer network as shown at 19 in Figure A.

Figure 5 illustrates the performance of the device before photopolymerisation as illustrated in Figure 3 and after photopolymerisation as illustrated in Figure 4. In particular, the electrooptic curve for the device before photopolymerisation is shown at 20 whereas that for the device after photopolymerisation is shown at 21. The device is of the type having polarisers 10 and 11 aligned with the polarising directions orthogonal so as to provide a normally-white or normally-bright device. The electrooptic curve 21 is substantially steeper than the curve 20 and this is substantially due to the reduction or suppression of the formation of the striped texture during switching.

As a result of locking the chirality of the polymer network, the possibility of formation of the striped texture is prevented or substantially reduced. Thus, it is possible to produce a 270° STN device with an alignment layer inducing a pre-tilt of 2° which can be commercially manufactured. Such a device is advantageous as compared with conventional STN devices where the twist is limited to 240° with alignment layers inducing a relatively high pre-tilt, for instance greater than 4°. Moreover, it is possible to avoid the use of commercially unviable evaporated alignment layers, such as silicone oxide, which would otherwise be required in order to provide high pre-tilt alignment layers permitting a 270° twist.

Figure 6 is an electrooptic curve for a device of the type shown in Figure 4 but with the polarisation directions of the polarisers 10 and 11 parallel to each other to provide a normally-black or a normally-dark display. The curves 21 and 22 are obtained for switching in both directions between dark and bright states and illustrate that devices of the type shown in Figure 4 are substantially free from hysteresis.

The use of a networked polymer as compared to a side chain polymer provides more stable polymer orientation and avoids hysteresis in the electrooptic curve. Additionally, the use of low pre-tilt alignment layers reduces device switching times so that the required time to switch between two states of a typical device may be of the order of 40 milliseconds.

The device shown in Figure 4 is of the transmissive type whereas Figure 7 illustrates a device of the reflective type. In this case, the polariser 11 is omitted and the electrode 15 is replaced by a combined electrode and mirror 25. Otherwise, the device may be of the same type as illustrated in Figure 4 and may be made in the same way.

The liquid crystals of the mixtures 19 shown in Figures 4 and 7 are of the positive dielectric anisotropy type and the photopolymerisation of the chiral and non-chiral prepolymers having at least two polymerisable groups (diacrylates in the examples specifically described hereinbefore) occurs with no applied field across the liquid crystal cell. However, it is also possible to use nematic liquid crystal of negative dielectric anisotropy. In this case, as shown in Figure 8, a signal generator 16 applies a sufficiently high electric field across the mixture in the cell during photopolymerisation so that the liquid crystal is substantially planar during the polymerisation. This results in a mixture 27 which, when the field is removed, comprises a planar polymer network with a homeotropic liquid crystal.

CLAIMS:

- 1 A supertwisted nematic liquid crystal device comprising first and second substrates defining therebetween a cell containing a mixture of a nematic liquid crystal and a helical polymer network.
- 2 A device as claimed in claim 1, in which the nematic liquid crystal in the cell has a twist angle of between substantially 180° and substantially 360°.
- 3 A device as claimed in claim 2, in which the twist angle is greater than 240°.
- 4 A device as claimed in claim 2, in which the twist angle is substantially equal to 270°.
- 5 A device as claimed in any one of the preceding claims, in which the nematic liquid crystal in the cell has a pre-tilt angle less than 4°.
- 6 A device as claimed in claim 5, in which the pre-tilt angle is substantially equal to 2°.
- 7 A device as claimed in any one of the preceding claims, in which at least one of the first and second substrates has an alignment layer for inducing planar alignment.
- 8 A device as claimed in any one of the preceding claims, in which the polymer of the network is a networked polymer.
- 9 A device as claimed in claim 13, in which the polymer comprises at least one polymerised chiral prepolymer having at least two polymerisable or crosslinkable groups.
- 10 A device as claimed in claim 9, in which the prepolymer comprises a diacrylate.

- 11 A device as claimed in any one of the preceding claims, in which the polymer network comprises at least one per cent by weight of the mixture.
- 12 A device as claimed in claim 11, in which the polymer comprises at least 1.5 per cent by weight of the mixture.
- 13 A device as claimed in any one of the preceding claims, in which the polymer network comprises less than 20 per cent by weight of the mixture.
- 14 A device as claimed in claim 13, in which the polymer network comprises less than ten per cent by weight of the mixture.
- 15 A device as claimed in claim 14, in which the polymer network comprises less than five per cent by weight of the mixture.
- 16 A device as claimed in any one of the preceding claims, in which the cell is disposed between first and second polarisers.
- 17 A device as claimed in claim 16, in which the first and second polarisers have linear polarising directions oriented at between 0° and 90° with respect to each other.
- 18 A device as claimed in any one of claims 1 to 15, in which the cell is disposed between a polariser and a reflector.
- 19 A method of making a supertwisted nematic liquid crystal device, comprising juxtaposing first and second substrates to define therebetween a cell, filling the cell with a mixture comprising a nematic liquid crystal and a chiral prepolymer, and polymerising or crosslinking the prepolymer to form a polymer network.
- 20 A method as claimed in claim 19, in which the mixture comprises a non-chiral prepolymer in addition to the chiral prepolymer.

21 A method as claimed in claim 19 or 20, in which the prepolymer is a networkable prepolymer.

22 A method as claimed in any one of claims 19 to 21, in which the chiral prepolymer has at least two polymerisable or crosslinkable groups.

23 A method as claimed in claim 22, in which the prepolymer comprises a diacrylic.

24 A method as claimed in any one of claims 19 to 23, in which the nematic liquid crystal in the cell has a twist angle of between substantially 180° and substantially 360°.

25 A method as claimed in claim 24, in which the twist angle is greater than 240°.

26 A method as claimed in claim 25, in which the twist angle is substantially equal to 270°.

27 A method as claimed in any one of claims 19 to 26, in which the nematic liquid crystal in the cell has a pre-tilt angle less than 4°.

28 A method as claimed in claim 27, in which the pre-tilt angle is substantially equal to 2°.

29 A method as claimed in any one of claims 19 to 28, comprising forming on at least one of the first and second substrates, prior to the juxtaposition, an alignment layer for inducing planar alignment.

30 A method as claimed in any one of claims 19 to 29, in which the prepolymer comprises at least one per cent by weight of the mixture.

31 A method as claimed in claim 30, in which the prepolymer comprises at least 1.5 per cent by weight of the mixture.

32 A method as claimed in any one of claims 19 to 31 in which the prepolymer comprises less than 20 per cent by weight of the mixture.

33 A method as claimed in claim 32, in which the prepolymer comprises less than ten per cent by weight of the mixture.

34 A method as claimed in claim 33, in which the prepolymer comprises less than five per cent by weight of the mixture.

35 A method as claimed in any one of claims 19 to 34 in which the liquid crystal has positive dielectric anisotropy and the polymerising or crosslinking is performed in the absence of an applied field across the cell.

36 A method as claimed in any one of claims 19 to 34, in which the liquid crystal has negative dielectric anisotropy and, during the polymerising or crosslinking, a field which provides planar alignment of the liquid crystal is applied across the cell.



The
Patent
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16

Application No: GB 9719862.6
Claims searched: 1 to 30

Examiner: G M Pitchman
Date of search: 30 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G2F (FCD)

Int Cl (Ed.6): G02F 1/1333 G02F 1/139

Other: ONLINE: EDOC WPI JAPIO INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	EP 0750211 A1 (SEIKO EPSON)-see column 6 line 40 to column 7 line 14	1-8
X	EP 0749031 A1 (SEIKO EPSON)-see page 3 line 54 to page 4 line 10	1-8
X	Patent Abstracts of Japan CD Ser No 9702 &JP9053074	1-30
X	Patent Abstracts of Japan vol. 95 no.4 & JP7110469	1-30
X	IEICE TRANS. ELECTRON. VOL. E79-C NO. 8 AUGUST 1996 pages 1058-1061	1-30

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.



The
Patent
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II

Application No: GB 9719862.6
Claims searched: 1 to 30

Examiner: G M Pitchman
Date of search: 26 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.P): G2F (FCD)

Int Cl (Ed.6): G02F 1/1333 G02F 1/139

Other: ONLINE: EDOC WPI JAPIO INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	EP 0750211 A1 (SEIKO EPSON)-see column 6 line 40 to column 7 line 14	1-8
X	EP 0749031 A1 (SEIKO EPSON)-see page 3 line 54 to page 4 line 10	1-8
X	Patent Abstracts of Japan CD Ser No 9702 & JP9053074	1-30
X	Patent Abstracts of Japan vol. 95 no.4 & JP7110469	1-30
X	IEICE TRANS. ELECTRON. VOL. E79-C NO. 8 AUGUST 1996 pages 1058-1061	1-30

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.